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WATER DELUGE FIRE PROTECTION SYSTEM FOR CONVEYOR LINES TRANSPOR--ETC(U)
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WATER DELUGE FIRE PROTECTION SYSTEM FOR CONVEYOR LINES TRANSPORTING HIGH EXPLOSIVES

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U.S. ARMY ARRADCOM

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DOVER, NEW JERSEY

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Munition production facilities transporting high explosives from one station to another on conveyor lines require fire protection. Design criteria and procedures for a water deluge system with a capability of detecting and functioning effectively to extinguish a fire following a detonation from a 60-lb box of flake Composition B are outlined in this design package.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

SI UNITS

The following conversion factors are given as a convenience in converting to SI units the English units used in this design package.

1 inch	=	25.40 mm
1 foot	=	0.305 m
1 ft^2	=	0.0929 m^2
1 cubic foot	=	0.0283 m^3
5/9 (°F-32)	=	°C
1 gallon	=	3.785 litres
1 gpm	=	3.785 litres/minute
1 gpm/sq ft	=	40.746 litre/min m^2
1 pound (mass)	=	0.454 kg
1 pound (force)	=	4.48 N
1 psi	=	6.895 k Pa
1 Btu	=	1.055 k J
1 Btu/hr/sq ft	=	3.155 W/m^2

I. INTRODUCTION

Within munitions production facilities, bulk high explosives (flake Composition B or TNT) are transported in 60-lb boxes from receiving magazines to plant processing areas via continuous belt conveyors or overhead suspension carriers. Propagation of an unwanted fire or explosion along the conveyor system poses a significant hazard to life and property.

Because of the potential effects of blast damage to the detection system and water supply lines, a specialized fire protection system is needed. This system must have the capability to function effectively following detonation of a 60-lb box of flake explosives and subsequently extinguish the resulting fire.

Design criteria and procedures for a fire protection system with these capabilities are outlined in this design package. This design incorporates a rapid-response water deluge system applicable to fire protection requirements for conveyor lines that transport flake Composition B or TNT in boxes not exceeding 60 lb in weight.

II. GENERAL DESCRIPTION OF THE WATER DELUGE SYSTEM

A. DESIGN FACTORS

In designing a fire protection system, the following basic engineering elements must be considered:

- Area(s) to be protected
- Type of extinguishing agent
- Agent storage system
- Agent delivery system
- Fire detection system
- Signaling system
- Control system
- Installation
- Maintenance
- Reliability
- Cost

B. DELUGE SYSTEM

The specialized fire protection system selected for this application is a water deluge system rated at a nominal 0.5 ± 0.1 gpm/sq ft over the conveyor belt area and 0.2 to 0.5 gpm/sq ft over the floor areas immediately adjacent to the high explosives transport system. The system is zoned and looped; for longer lines the water distribution system is divided into 100-ft modular units.

To provide maximum protection from blast effects, the water distribution pipes are to be buried in the ground either under or adjacent to the conveyor line housing structures. Water is distributed to the critical area via straight stream nozzles attached to uprisers from the distribution piping. The nozzles are located approximately 1 foot above floor level. A crossed, interlaced stream pattern is used to provide water distribution to the upper surfaces of the conveyor line. Each nozzle is directed to a central point above the conveyor line approximately 35 feet from the upriser, either "upstream or downstream" of the individual uprisers. The fire stream is elevated to provide a relatively even distribution over the conveyor line area from about 20-25 feet to 40-45 feet from the nozzle.

C. DETECTION SYSTEM

Fires or explosions are detected using a fast-response, supervised ultraviolet detection system. Each modular water distribution area is cross-zoned by two detector units. Mounted above the conveyor line and enclosed in explosion-proof and waterproof housing, the detectors have a high band pass efficiency to ultraviolet radiation in the 1800 to 1900 A spectral region. Detector power and signal lines are buried for maximum protection from blast damage. Signals from the detectors are monitored by an integrated signal control unit that performs four functions: (1) sensing of fire or explosion event, (2) basic supervision of all critical circuits, (3) actuation of the water deluge valve, and (4) visual and digital alarm readouts. Each controller can monitor up to eight detectors.

Fire suppression action is initiated from the control unit, upon indication of a fire or explosion, which either opens a solenoid or explosive water valve to the module. For this application a normal, fast-response solenoid valve is recommended.

III. DETAILED DESCRIPTION OF WATER DELUGE SYSTEM

A. WATER DISTRIBUTION

1. General

As designed for this application, the water distribution system is a looped, fully loaded wet-pipe deluge system capable of providing an area coverage of 0.5 gpm/sq ft over the conveyor system and from 0.2 to 0.5 gpm/sq ft over immediately adjacent areas. The system is configured into 100-ft modular sections corresponding to limitations caused by the fire detection system. To prevent blast damage to the system, all distribution piping is installed underground.

Each upriser contains two nozzles located approximately 1 ft above ground level. The water spray pattern consists of a system of crossed, opposed fire streams with adjustments for elevation and azimuth provided by two street ells. Each nozzle is a solid-stream nozzle having a dispersion pattern approximately 3 ft wide at 20 ft and 5 ft wide at 45 ft. Nozzles are operated at a nominal water pressure between 20-40 psig, and each nozzle requires an incoming pressure head of 60-70 psig. The system is actuated by means of a normally closed solenoid valve, and provision is made for draining.

2. Primary Water Supply

For general requirements of primary water supply systems, refer to NFPA Nos. 13-75 and 15-73.

Water for the deluge system will come from the in-plant industrial water supply reserved for emergency fire use. Volumetric flow requirements will necessarily depend on the specific conveyor system size and configuration, but as a minimum, the flow volume must be of sufficient capacity to operate five adjacent modules for a period of 60 minutes. The primary supply water main will be installed at least 4 ft below the ground surface and, if necessary, protected from ground shock waves traversing soil-rock formation by a sand or suitable earthen bed at least 12 in. from the rock.

3. Modular Distribution System

Each module consists of four parts: (1) looped water piping system, (2) control valving, (3) uprisers with attached spray nozzles, and (4) a drain and refill system. Each module should be hydraulically designed in accordance with the procedures outlined in NFPA 15-73, section A-7010 (see Appendix).

Schedule 40 steel piping shall be used for the distribution piping (ASTM A 120, Schedule 40, AWWA C200, AWWA C202-1964, AWWA C201-1966). All joints will be threaded or welded. If threaded, they shall conform to ASTM or Federal Standards for materials and construction. If welded, they shall conform to AWWA-C206-62. In areas where electrolytic ground corrosion may be a factor, all joints should be bonded and cathodic protection provided. Internal corrosion protection coatings should conform with AWWA C203-66 or AWWA C205-71. Outside coatings to prevent soil corrosion should be applied when necessary. Fittings used should be appropriate for the same range of working pressures as the pipe with which they are used and should be listed or approved. Installation

should conform with standard industrial practices, including provisions outlined in The Fire Protection Handbook, 4th Edition, pp 11-12 to 11-16. When necessary, thrust blocks shall be used.

Control valving shall consist of a solenoid or fluidic (normally closed) valve and a hand-operated gate valve (normally open). Listed commercially available valves should be used. Valves should be installed in a pit as near to the fire main as reasonably practical. Electrical or fluidic control circuitry should be buried to provide protection from ground shock damage. The control valves should have as rapid a response time as reasonably possible. Although more rapid response times are desirable, a response time of 1 to 5 seconds is sufficient for this application. (For Composition B and TNT flake explosive the expected time to development of significant secondary fires is at least 20 to 30 seconds).

Eight uprisers are used for each module, located on 25-ft centers along each side of the module and staggered as indicated in Figure 1. To provide an even flow distribution, the uprisers are fed by a double looped system. Either Schedule 40 1-1/4 in. steel pipe or heavier construction can be used. It has been determined that 1-1/4 in. Schedule 40 pipe can withstand blast and fragments resulting from a 60-lb detonation 3-1/2 feet away. Two nozzles are located at the top of each upriser on a "tree" consisting of one tee and two street ells for each nozzle. The elevation of the tee is approximately 1 ft above floor level. All tees for a given module will be installed at the same elevation (± 1/2 inch). Threaded joints are used for the tee and street ells to enable adjustments for elevation and azimuth. A Sprayco H 3/4 U00700, straight-stream nozzle can be used. A pressure actuated blow-off plug is to be used to seal the nozzles and prevent evaporation or leakage.

The uprisers can be located outside the canopy structure or run through the floor. If an outside location is used, provision must be made for openings in the wall structures. If the piping is run through the floor, a 1-1/2-in. clearance is necessary between the outside of the pipe and the concrete. The gap is to be filled with a flexible material, such as tar, and sealed on the surface with a smooth caulking agent. During installation care must be taken to prevent accumulation of explosive dust by tapering the caulking material to make a smooth convex taper to the floor.

Adjustments to the system are made by selective rotation of the nozzles using the two street ells. To do this, the nozzle is initially directed toward a point about 3 ft above the conveyor line, 30-35 ft away from the nozzle, and the street ells tightened. The water distribution pattern for a single nozzle provides coverage from about 20 to 45 ft over an area about 4 ft wide. One nozzle on each upriser is directed upstream,the other downstream. After all the nozzles have been installed on both the module being tested and the two adjacent modules, a final adjustment is made under normal operating conditions. Because the streams are interlaced and crossed, stream interactions occur, and the spray distribution is more disperse than a single, non-interaction stream. By adjusting these patterns, a proper coverage over the conveyor line (minimum application rate 0.5 gpm/sq ft) can be obtained. After the entire system has been adjusted, the street ells should be tack-welded in place.

For installations that may require larger volumetric flows than those provided by the Sprayco H 3/4 U00700 nozzles, similar results may be obtained using either the Sprayco 1U00100 or Sprayco 1-1/ 4 U001800 straight-stream nozzles. Flow rates for these nozzles are shown in Figure 2.

An inorganic antifreeze additive with a corrosion inhibitor shall be added to the water container between the valves for each section and each nozzle. For this purpose organic depressants such

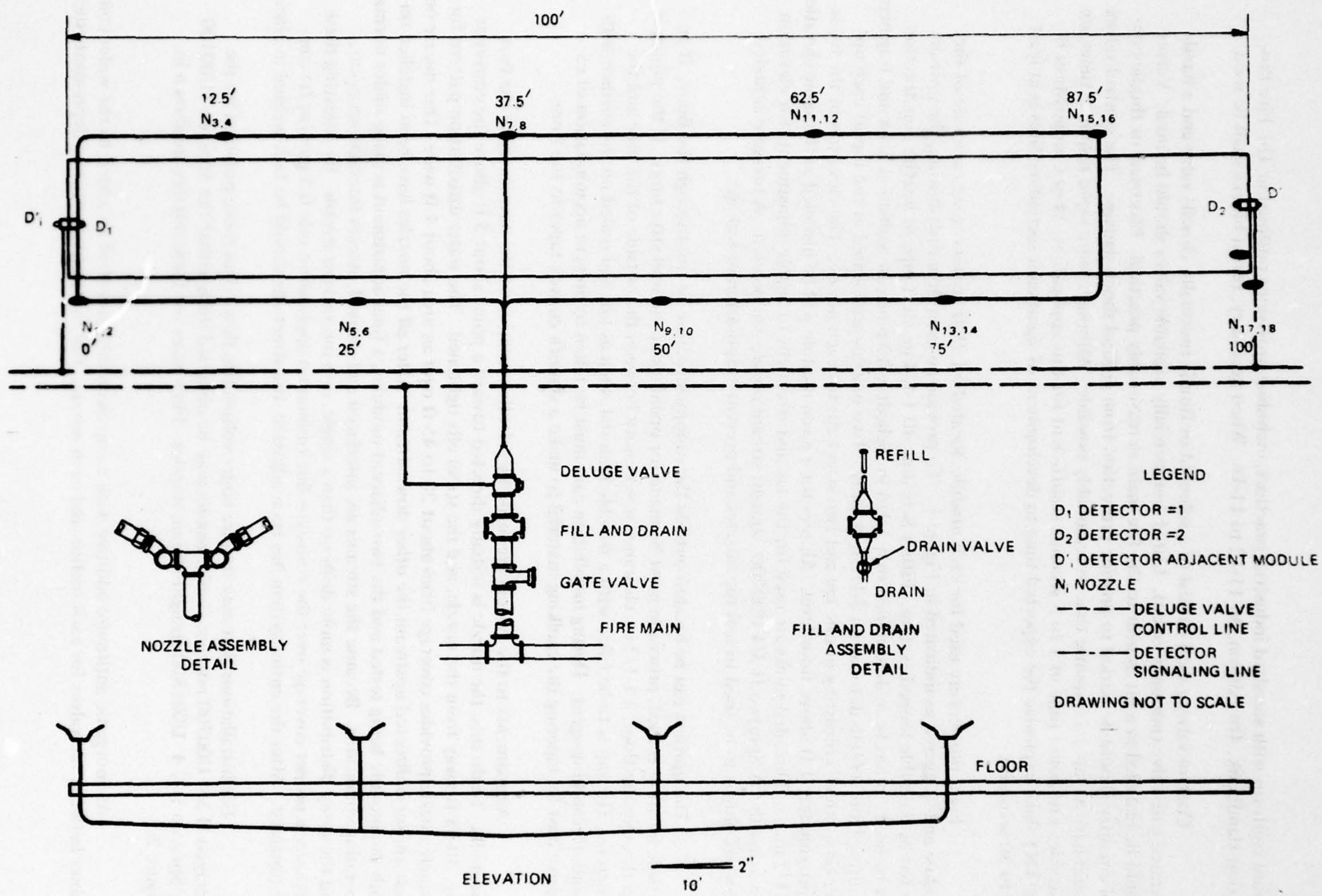

FIGURE 1. SCHEMATIC OF MODULAR FIRE PROTECTION SYSTEM

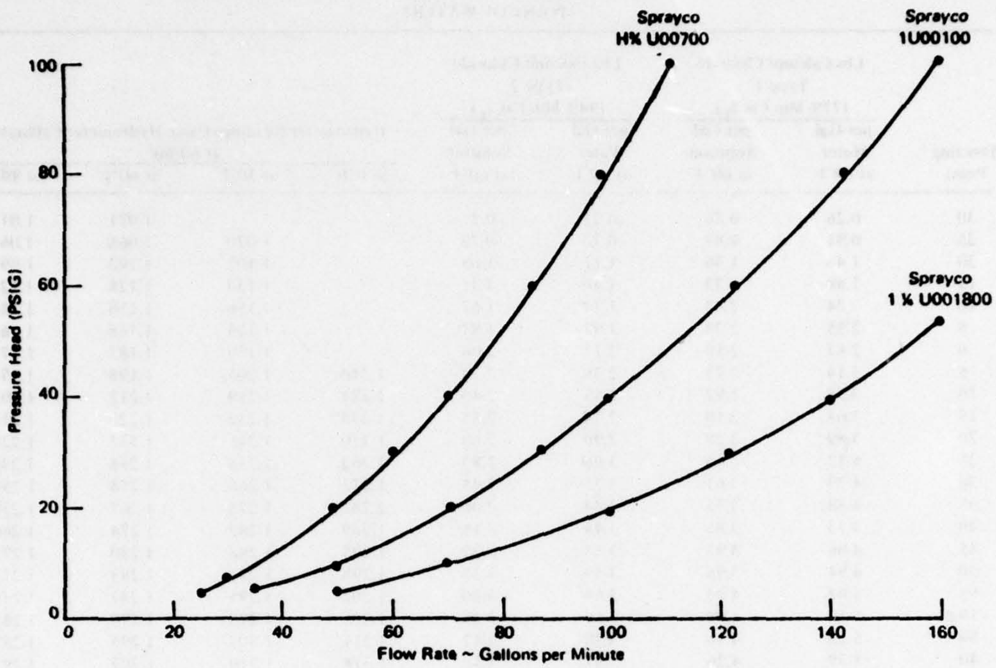

FIGURE 2. FLOW RATES FOR SELECTED 0° ANGLE SOLID STREAM NOZZLES

as *diethylene glycol*, *ethylene glycol*, glycerine, or propylene glycol, shall not be used, nor will sodium chloride. The freezing point of the solution shall be at least 10 deg F lower than the lowest temperature recorded at the plant site, as adjusted on a monthly basis.

A recommended freezing point depressant is calcium chloride (ASTM Specification D-98-68) with a corrosion inhibitor. The lowest temperature to be used for $CaCl_2$ is −59.8 deg F. A suitable corrosion inhibitor can be made by the addition of 0.5 percent sodium chloride to a 100-lb bag of Type 1 or to an 80-lb bag of Type 2 calcium chloride. If large quantities of an inhibitor are required, add 27 lb of caustic soda for each 100 lb of dichromate. Equivalent inorganic salts with inhibitors may also be used. The freezing temperature of the solution shall be calibrated using hydrometer readings in accordance with Table 1. Either Type 1 or Type 2 $CaCl_2$ may be used. In preparing solutions, the quantity of water should be measured and the required amount of $CaCl_2$ added to the water while stirring. Losses by evaporation can be adjusted by adding water and stirring.

The water in the uprisers and exposed lines must also be protected from freezing during cold weather. To do this, a drain and refill assembly is installed between the gate valve and the automatic deluge valve. To provide complete drainage of the system, all lines are to be sloped toward this drain. The slope shall be at least one in. per 10 ft of line. To minimize leaking, all the tees supporting the nozzles for a given module should be at the same elevation (± 1 in.). A number of designs can be employed for the drain and refill assembly. A possible design could consist of an in-line reducing cross with a fill-line upriser and a bottom hand-operated valve. The top of the upriser should be the same elevation as the nozzles, and sufficient clearance should be provided under the hand valve to expedite removal of the liquid.

TABLE 1. CALCIUM CHLORIDE SOLUTIONS TO DEPRESS FREEZING POINT OF WATER*

Freezing Point	Lbs Calcium Chloride Type 1 (77% Min $CaCl_2$) per Gal Water at 60°F	Lbs Calcium Chloride Type 1 (77% Min $CaCl_2$) per Gal Solution at 60°F	Lbs Calcium Chloride Type 2 (94% Min $CaCl_2$) per Gal Water at 60°F	Lbs Calcium Chloride Type 2 (94% Min $CaCl_2$) per Gal Solution at 60°F	Hydrometer Readings Using Hydrometer Calibrated at 60/60° at 0°F	at 30°F	at 60°F	at 90°F
30	0.26	0.26	0.21	0.2			1.021	1.017
25	0.91	0.87	0.73	0.72		1.070	1.066	1.062
20	1.46	1.36	1.11	1.08		1.107	1.102	1.097
15	1.88	1.73	1.46	1.41		1.133	1.128	1.123
10	2.24	2.03	1.74	1.67		1.156	1.150	1.144
5	2.55	2.28	1.97	1.87		1.174	1.168	1.162
0	2.83	2.50	2.17	2.06		1.190	1.183	1.177
5	3.14	2.73	2.38	2.24	1.210	1.205	1.198	1.191
10	3.38	2.92	2.55	2.40	1.224	1.219	1.212	1.205
15	3.64	3.10	2.74	2.55	1.238	1.232	1.225	1.218
20	3.89	3.28	2.90	2.69	1.250	1.245	1.237	1.229
25	4.13	3.45	3.06	2.83	1.262	1.256	1.248	1.240
30	4.37	3.61	3.21	2.95	1.272	1.266	1.258	1.250
-35	4.58	3.75	3.34	3.06	1.282	1.275	1.267	1.259
40	4.73	3.85	3.44	3.15	1.289	1.282	1.274	1.266
-45	4.86	3.93	3.53	3.22	1.295	1.288	1.280	1.272
-50	4.94	3.98	3.59	3.27	1.298	1.291	1.283	1.275
-55	5.02	4.03	3.64	3.30	1.302	1.295	1.287	1.279
-59.8	5.10	4.08	3.69	3.35	1.306	1.298	1.290	1.282
-50	5.23	4.16	3.78	3.42	1.311	1.303	1.295	1.287
-40	5.39	4.26	3.87	3.50	1.318	1.310	1.302	1.293
30	5.56	4.36	4.00	3.60	1.324	1.317	1.308	1.299

Fire Protection Handbook, 14th Edition, NFPA.

B. FIRE DETECTION

1. General

An automatic fire detector will be incorporated into the system to detect the presence of a fire or explosion and initiate fire suppression action. Although a specific type of detector is recommended, other detectors may be used if it can be demonstrated that the unit meets or exceeds the criteria established for this application i.e., sensitivity, speed of response, stability, and reliability. Any device selected will require appropriate approval and will be installed and tested in accordance with specifically authorized procedures based on manufacturer's recommendations. It is intended that the ensuing design criteria be used and applied by persons knowledgeable in the field of fire protection engineering.

2. Flame Detector

a. Type

A line-of-sight, ultraviolet flame detector with a detonation response time of less than 20 milliseconds is recommended. Detonation response time is defined as the elapsed time between the rupture of a break wire imbedded in the surface of an uncased explosive charge (1/4 lb of C-4) and the subsequent initiation of water deluge action caused by a related signal function of the detector control circuit. To establish the detonation response time, the detector must be located at least 50 ft from the test charge.

This detector must also have a fire response time of less than 100 milliseconds. Evaluation of the fire response time must be accomplished by using a base design fire having no more than 4 sq in. of exposed flake high explosive surface, with the flame detector located at least 100 feet from the base fire.

b. Field of View

The field of view of the detector must be unobstructed to avoid interference with its response to a base design fire located on the conveyor line. When located at an elevation 10 ft above the floor surface, the detector must be able to respond to a fire on the floor immediately below or a fire on the conveyor line 100 ft distant.

c. Housing

The housing or protective cover of the detector must be explosion proof and waterproof. The primary purpose of the detector housing is to prevent ignition or detonation of explosive dust as a result of detector operation. A secondary purpose of the housing is to limit damage to the detector from a fire or explosion. The housing must be constructed so as to facilitate removal of the detector for cleaning and maintenance. For ease of cleaning, all surfaces of the housing must be smooth. Design of the detector housing must also be such as to avoid the occurrence of friction-initiated fires resulting from cover removal.

d. Location and Support Structure

A minimum of two detectors are required for each 100-ft conveyor module, each installed 9 ft (± 1 ft) above the floor. More detectors might be required for conveyor lines that have sharp bends or traversing elevation. One detector will be installed at each end of the module, each with a viewing angle that permits cross-zoned coverage of the module. There are three reasons for this arrangement: (1) increased reliability inherent in cross-zoning, (2) need for the controller unit to identify the specific module in which a fire/explosion occurs, and (3) maintenance of detection capability in the event of a detonation occurring near the detector location. Using this arrangement, two detectors can be mounted back-to-back on the same support structure, each monitoring a different zone.

Two-inch Schedule 40 steel pipe is recommended for detector supports, which must be capable of withstanding transient blast overpressures of at least 2 psia with the detector attached. Electrical conduit is not satisfactory as a sole support and will not be used as such. Support hardware will be designed for easy adjustment to a minimum angle of 45 degrees, permitting a 90-degree field of view.

Supports will be firmly anchored in the ground and sealed to prevent explosive dust accumulation. Welded pipe fittings are recommended to reduce dust accumulation on exposed threaded surfaces. For new installations, supports should be installed through the floor foundation. In this configuration a 3/8-in. clearance should be left between the pipes and the cement or concrete materials. This clearance should be filled and sealed in accordance with ASTM construction standards.

e. *Electrical Power Supply*

Electrical wiring required for detector power and signaling purposes will be installed in rigid metal conduit pipe in accordance with NFPA standards for hazardous installations. With authorization, the conduit may be installed inside the detector support pipes. If necessary, the conduit will be ducted across the ceiling and down the wall into a buried, blast and fragment resistant cable race. The underground cable race will be separated from the foundation by at least 2 ft to protect lines from ground shock wave blast damage. For soil conditions in which the cable is adjacent to rock or other similar materials, special precautions may be necessary. Exposed lines will be kept to a minimum and also as short as possible.

Power requirements for each detector must meet or exceed those specified by the detector manufacturer. The power supply will include emergency power capability as specified in NFPA codes.

f. *Recommended Equipment*

Fire and explosion detection equipment recommended for this system is the Det-Tronics C7050-B-3001 detector unit and housing assembly. This unit can be used effectively with the Det-Tronics R7300-F supervised controller. Either a 24- or 110-volt a.c. line may be used.

g. *Testing*

The detector system will be checked out after installation in accordance with the requirements of the NFPA codes and manufacturer's instructions. The testing and checkout of the installed system can be implemented by the following procedure: Place a benzamatic torch or similar flame source on the conveyor line at a distance of 100 ft. If the torch is in the field of view of the detector, a signal should be observed. Adjustments can be made to the detector as necessary. To provide adjustment capability, either a swivel mount or a combination of two street ells and a base plate, or a similar arrangement, must be provided. The controller system recommended continuously supervises critical functioning of all electrical circuits, including a digital readout of any malfunctioning subsystems. In addition, an annual inspection should be made of the detectors and wiring by a qualified fire detection inspector to verify that their field of view meets established requirements and specifications and that corrosion and/or other problems are not present.

C. CONTROL AND ALARM SYSTEMS

1. General

The scope of this section is limited to a general outline of the purpose and functions of the control and alarm systems necessary for the specialized fire suppression system. Three major control systems are required. First, a control system is needed to monitor fire detector signals and perform periodic checks on the integrity of all electrical subsystems required for detection. Another control system is needed to actuate water deluge action. This function involves the selection and control of individual fire zones, as well as alarms and indicating signals required to provide information to fire safety personnel. Other control systems may be required for other purposes, such as actuation of fire pumps, but it is assumed that such systems are part of the normal functions of the plant fire protection system.

2. Detector Monitoring Controls

Each fire zone consists of a 100-ft segment of conveyor line that is monitored by a cross-zoned system of fire detectors. Two detectors are mounted back-to-back at 100-ft intervals along the line. Because a detector having a 90-degree field of view, oriented 45 degrees to the vertical, will see a fire or explosion in an adjoining fire zone, it is possible to have a number of zones actuated. The result of actuating too many fire zones simultaneously is that the volumetric flow capabilities of the fire mains may be exceeded. One of the primary functions of the controller is to identify the zone in which a fire or explosion occurs and to initiate water deluge action in that zone and, at the least, the two zones immediately adjacent.

Selection of the number of zones to be actuated is determined by the specific plant configuration and material flow processes. The back-to-back installation of detectors provides an array of signals that permit the controller circuit logic to determine the specific location of the fire/explosion. The logic must also be capable of determining the fire location if a detonation occurs near the detectors unit (100 feet), destroying two units before they can actuate the system.

Commercial equipment capable of performing these functions can be obtained from detector manufacturers. Specifications for specific system requirements should be formulated after discussion with the manufacturer. For example, in the event of an explosion/fire in the central region of a fire zone, the two cross-zoned detectors protecting the zone send a signal to the controller. Both detectors must operate in order to actuate fire suppression action. For the zones immediately adjacent to the fire zone, only one detector is actuated for each zone. The controller logic must be able to scan this information and send the necessary power to the valves controlling the adjacent zones. If two back-to-back detectors are destroyed before signaling the controller, logic must be capable of determining this fact and provide suppressive action to the two zones affected.

Another function of the controller is to monitor critical subsystems and components of the detection system and provide an indication of malfunction. The system's functions that must be monitored include, but are not necessarily limited to:

- the detector tube
- the detector window
- power supply
- electrical continuity to the detector
- electrical continuity to the valving.

Preferably, these functions should be monitored at a fire control station remotely located from the conveyor line.

3. Water Deluge Controls

Water deluge action for each fire zone is controlled by applying current to a solenoid valve or other device to initiate action in one or more fire zones. The general requirement is that sufficient power be switched to actuate the flow control devices. The specific power requirements depend on the specific installation. Major parameters that affect the selection are the type and size of the valving device and the distance from the controller to the affected fire zone. Power requirements include both normal and emergency power sources of sufficient capacity to function effectively. Electrical cables and/or other lines required should be installed underground to prevent blast damage; any exposed wiring must be fully protected by adequate shielding. A sufficient depth of installation is 2 ft, and the cabling should be at least 2 ft from any foundation structures.

Periodic checks must be made in the cabling for electrical continuity between the controller and the individual valves. Preferably, all lines should be fully supervised using the logic modules of a centralized controller.

4. Alarm and Malfunctions Signaling

In addition to the automatic actuation of the fire suppression system, the controller must send alarms to the central plant fire department and also alert the employees in the areas affected. These alarm functions are required as outputs from the controller. Since those are usually included in the design of a fire protection system, it is sufficient to provide the alarms required for normal plant operations. Reference is made to the NFPA codes for specific requirements.

In addition to the **alarms**, critical detector and control valve circuitry should be continuously monitored. The output of this monitoring system should be displayed using either visual indicator lamps or a digital code output to indicate the source of trouble.

5. Recommended Equipment

The specific controls equipment recommended for this application is the Det-Tronics R7300-F supervised controller used with their C7050-B-3001 detector unit. This system can provide the supervision required. However, modifications must be made to the control logic circuits to provide detailed fire zone identification and display mini-boards must be developed for each installation. Each controller must supervise eight detectors and 4 cross-zoned fire zones.

D. INSTALLATION AND DESIGN CODES

All materials and equipment shall be designed and installed in accordance with the instructions contained in this document and the applicable portions of NFPA, Code Nos. 72A, B, C, D, and E, and Article 760, Fire Protective Signaling Systems of the National Electrical Code, NFPA No. 70-1975.

E. SPECIFIC EQUIPMENT RECOMMENDATIONS

Specific equipment that is recommended herein may be replaced by equivalent equipment following review and approval by appropriate authorities.

IV. APPLICABLE STANDARDS AND SPECIFICATIONS

A. FEDERAL SPECIFICATIONS (FED. SPEC.)

QQ-C-40 & Am-2.	Calking: Lead Wool and Lead Pig.
WW-P-421c.	Pipe: Cast Gray and Ductile Iron, Pressure (For Water and Other Liquids).
WW-P-521F.	Pipe Fittings, Flange Fittings, and Flanges, Steel and Malleable Iron (Threaded and Butt-Welded), 150 Pound.
WW-P-541D/GEN. (GSA-FSS).	Plumbing Fixtures (Land Use) (General Specification).
WW-V-51E & Int. Am-2 (GSA-FSS).	Valve, Angle, Check, and Globe, Bronze (125), 150, and 200 Pound, Threaded End, Flange End, Solder End, and Brazed End, for Land Use).
WW-V-54D & Int. Am-1 (GSA-FSS).	Valve, Gate, Bronze (125, 150, and 200 Pound, Threaded End, Flange End, Solder End and Brazed End, for Land Use).
WW-V-58B.	Valves, Gate, Cast Iron, Threaded and Flanged (for Land Use).

B. MILITARY SPECIFICATION (MIL. SPEC.)

MIL-A-17472B & Notice 1.	Asbestos Sheet, Compressed (Gasket Material).

C. U.S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS (NBS) HANDBOOK

H28.	Screw-Thread Standards for Federal Services (Part I (1969); Parts II and III (1957); reprinted December 1966 with corrections).

D. AMERICAN NATIONAL STANDARDS INSTITUTE, INC. (ANSI).

B16.26-1975.	Cast Copper Alloy Fittings for Flared Copper Tubes.
B18.2.1-1972.	Square and Hex Bolts and Screws.
B18.2.2-1972.	Square and Hex Nuts.
B112.1-1970.	Hose Valves for Fire Protection Service.

E. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 120-73.	Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses.

A 307-74.	Carbon Steel Externally and Internally Threaded Standard Fasteners.
A 325-74.	High-Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers.
A 575-73.	Merchant Quality Hot-Rolled Carbon Steel Bars.
A 576-74.	Steel Bars, Carbon, Hot Rolled, Special Quality.
B 88-75a.	Seamless Copper Water Tube.
D 1869-66 (R 1972).	Rubber Rings for Asbestos-Cement Pipe.

F. AMERICAN WATER WORKS ASSOCIATION (AWWA)

B300-75.	Hypochlorites.
B301-59.	Liquid Chlorine.
C200-75.	Steel Water Pipe 6 Inches and Larger.
C203-73.	Coal-Tar Protective Coatings and Linings for Steel Water Pipelines–Enamel and Tape–Hot-Applied.
C207-55.	Steel Pipe Flanges.
C400-75.	Asbestos-Cement Pressure Pipe, 4 in. through 24 in., Water and Other Liquids.
C500-71.	Gate Valves–3 through 48 in.–for Water and Other Liquids.

G. FACTORY MUTUAL SYSTEM (FM) PUBLICATION

Approval Guide (1974; Suppl. I, Mar 74, Suppl. II, July 74).

H. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

No. 13-1975.	Sprinkler Systems.
No. 14-1974.	Standpipe and Hose Systems.
No. 15-1973.	Water Spray Fixed Systems for Fire Protection.
No. 24-1973.	Outside Protection.

I. UNDERWRITERS' LABORATORIES, INC. (UL) PUBLICATION

Fire Protection Equipment List (January 1975, with Quarterly Supplements).

J. MATERIALS SPECIFICATIONS

1. **Squarehead Bolts and Heavy Hexagon Nuts: ANSI B18.2.1 and B18.2.2 and ASTM A 307, A 575, or A 576.**

2. **Calking Lead: Fed. Spec. QQ-C-40, Type I.**

3. **Chlorine, Liquid: AWA B301.**

4. **Flange Dimensions: ANSI B16.1 or AWWA C207.**

5. **Gages: Fed. Spec. GG-G-76, Class 1, Type I, Style A.**

6. **Flange Gaskets: Mil. Spec. MIL-A-17472.**

7. **Hypochlorite: AWWA B300.**

8. **Lubricant**

   a. ***Gasket Lubricant* shall be as recommended by the pipe manufacturer.**
   b. ***Thread-Cutting Oil* shall be an all-purpose lubricant free from animal or vegetable compounds.**

9. **Pipe For Aboveground Installation.**

   a. ***Copper Tubing:* ASTM B 88, Type K, annealed.**
   b. ***Steel Pipe:* ASTM A 120, Schedule 40, AWWA C200. In water-spray systems, and where required because of corrosive conditions, pipe shall be galvanized in accordance with ASTM A 120 or coated and lined in accordance with AWWA C203.**

10. **Pipe Fittings**

    a. ***For Aboveground Installation*, fittings are to be malleable iron. Cast iron may be used for installations located 200 feet or more from any explosives.**
    b. ***Cast Iron Fittings* shall conform to ANSI A21.10 or B16.1; type to match adjacent piping for underground water supply systems.**
    c. ***Malleable Iron Fittings* shall conform to Fed. Spec. WW-P-521; type to match adjacent piping.**

11. **Pipe Hangers**

    Hangers shall be in accordance with NFPA No. 13, and in accordance with UL requirements for use in sprinkler systems.

12. **Valves**

    a. ***Gate Valves:* Under 2-inch size valves shall be in accordance with Fed. Spec. WW-V-54; 2-inch to 3-inch size valves shall conform to the requirements of Fed. Spec. WW-V-54 or WW-V-58; 3-inch and above size valves shall meet the requirements of Fed. Spec. WW-V-58 or AWWA C500.**

b. *Check Valves:* Under 3-inch size valves shall meet the requirements of Fed. Spec. WW-V-51. Valves 3-inches and larger shall be iron body, bronze-mounted. All valves must be UL or FM (listed in Approval Guide) approved straightway type, suitable for vertical or horizontal installation with end connections as required to mate with piping in which the valve must be installed.

K. PLUMBING AND DRAINAGE INSTITUTE (PDI)

PDI-WH 201	Water Hammer Arresters (1965)

L. INSTALLATION WORKMANSHIP

1. General

All materials and equipment shall be installed in accordance with NFPA No. 13, NFPA No. 70, and NFPA No. 72A, 72B, 72C, and 72D. The system shall be installed by an experienced firm regularly engaged in the installation of fire protection sprinkler systems in accordance with NFPA standards.

2. Welding

Welding will be in accordance with NFPA No. 13.

3. Electrical

Electric equipment and wiring shall be in accordance with the recommendations outlined in this document and the National Electrical Code, NFPA 70-1975.

4. Pipe and Fittings

a. *Pipe:* Pipe used shall not be subject to a working pressure in excess of 25% of the hydrostatic pressure test required by ASTM A 120.

b. *Joints:* Joints generally shall be the threaded type. Shop welded joints in accordance with the provisions of NFPA No. 13 will be permitted. Flanged connections shall be provided where indicated or required by NFPA No. 13.

Threaded joints shall be cut with an approved thread-cutting oil and shall conform to NBS Handbook H28. Joints shall be made tight with a stiff mixture of litharge and glycerin or other approved thread-joint compound or tape. Not more than three threads shall show after the joint is made up.

Flanged joints shall be faced true, provided with 1/16-inch asbestos gaskets in accordance with Mil. Spec. MIL-A-17472, and made square and tight.

c. *Special Couplings:* Couplings approved for use in sprinkler systems may be used in place of unions and flanged connections where applicable.

d. *Fittings:* Fittings for aboveground piping shall be of a type specifically approved for use in sprinkler systems. Bushings shall be used only where standard fittings of the required size are not available. The use of bushings is further restricted to requirements of NFPA No. 13.

e. *Reducers:* Reductions in pipe sizes shall be made with one-piece reducing fittings. Bushings will not be acceptable, except that when standard fittings of the proper size are not available, single bushings of the face type will be permitted. Where used, face bushings shall be installed with the outer face flush with the face of the fitting opening being reduced. Bushings shall not be used in elbow fittings in more than one outlet of a tee, in more than two outlets of a cross, or where the reduction in size is less than 1/2 inch.

f. *Pipe Supports and Hangers:* The recommended methods and requirements for supporting of hanging pipe as set forth in NFPA No. 13 shall be mandatory.

g. *Pipe Sleeves:* Pipes passing through concrete or masonry walls or concrete floors shall be provided with pipe sleeves fitted into place at the time of construction. All rectangular and square openings shall be as detailed. Each sleeve shall extend through its respective wall or floor and be cut flush with each surface. Unless otherwise indicated, sleeves shall be of such size as to provide a minimum of 3/4-inch all-round clearance between the pipe and sleeves. Sleeves in bearing walls, waterproofing membrane floors, and wet areas shall be steel pipe or cast iron pipe. Sleeves in non-bearing walls, floors, or ceilings may be steel pipe, cast iron pipe, or galvanized sheet metal with lock-type longitudinal seam.

In addition to the pipe sleeves referred to above, pipes through floor waterproofing membrane shall be provided with a 4-pound lead flashing or a 16-ounce copper flashing, each within an integral skirt or flange. Flashing shall be suitably formed, and the skirt or flange shall extend not less than 8 inches from the pipe and shall set over the floor membrane in a solid coating of bituminous cement. The flashing shall extend up the pipe a minimum of 10 inches above the floor. The annular space between the flashing and the pipe shall be sealed as indicated. Pipes passing through floor waterproofing membrane may be installed through a cast iron sleeve with calking recess, anchor lugs, flashing-clamp device, and pressure ring with brass bolts. Waterproofing membrane at floors shall be clamped into place, and sealant shall be placed in the calking recess.

Pipes passing through wall waterproofing membrane shall be sleeved as described above. In addition, a waterproofing clamping flange shall be installed as indicated.

Where pipes pass through fire walls, fire partitions, or floors, a fire seal of asbestos rope, mineral wool, or similar noncombustible material shall be placed between the pipe and sleeve. Penetrations shall be as detailed and located where indicated.

h. *Escutcheons:* Escutcheons shall be provided at all finished surfaces where exposed piping passes through floors, walls, or ceilings. Escutcheons shall be fastened securely to pipe and shall be chromium-plated iron or chromium-plated brass, either one-piece or split-pattern, held in place by internal spring tension or setscrew.

i. *Drains:* The sprinkler system shall be provided with complete drainage facilities as indicated and in accordance with NFPA No. 13.

j. *Protection Against Freezing:* Supply pipes or risers that pass through unheated spaces in or under buildings and are exposed to freezing temperatures shall be protected from freezing as indicated or in accordance with applicable methods in NFPA No. 13.

k. *Protection of Piping in Seismic Zones* shall be mandatory: Methods of protection shall be in accordance with applicable requirements of NFPA No. 13.

M. SPRINKLERS AND SPRAY NOZZLES

Sprinklers and spray nozzles shall conform to the recommendations outlined herein.

N. DISINFECTION

Before acceptance of the sprinkler system, each unit of the completed system shall be disinfected as specified herein. After pressure tests have been made, the unit to be disinfected shall be thoroughly flushed with water until all entrained dirt and mud have been removed before introducing the chlorinating material. The chlorinating material shall be either liquid chlorine, calcium hypochlorite, or sodium hypochlorite, conforming to paragraph MATERIALS. The chlorinating material shall provide a dosage of not less than 50 parts per million and shall be introduced into the sprinkler lines in an approved manner. The treated water shall be retained in the pipe long enough to destroy all non-spore-forming bacteria. Except where a shorter period is approved, the retention time shall be at least 24 hours and shall produce not less than 10 ppm of chlorine throughout the line at the end of the retention period. All electrically or hand-actuated valves on the lines being disinfected shall be opened and closed several times during the contact period. The line shall then be flushed with clean water until the residual chlorine is reduced to less than 1.0 ppm. From several points in the unit, samples of water will be taken in properly sterilized containers for bacterial examination. The disinfection shall be repeated until tests indicate the absence of pollution for at least two full days. The unit will not be accepted until satisfactory bacteriological results have been obtained.

O. INSTRUCTIONS FOR TESTS, INSPECTION, OPERATION, AND PREVENTIVE MAINTENANCE

Prior to acceptance, one bound copy of complete instructions, including catalog cuts, diagrams, drawings, and other descriptive data covering the proper testing, operation, and maintenance of each type of system installed, and the necessary information for ordering replacement parts is required.

P. TESTS

Upon completion the new and existing sections of the system will be tested as required by NFPA Nos. 13 and 15 and as otherwise outlined in this document.

APPENDIX

This appendix has been reproduced from *National Fire Codes, Vol. 2, 1976*, Codes and Standards, National Fire Protection Association.

APPENDIX

A-7010. Hydraulic Calculation — General.

1. SUMMARY SHEET. The summary sheet (for sample summary sheet see Figure A-7010.a.) should contain the following information:

(a) Date.
(b) Location.
(c) Name of owner and occupant.
(d) Building or plant unit number.
(e) Description of hazard.
(f) Name and address of contractor.
(g) Authority having jurisdiction.

— SUMMARY SHEET — HYDRAULIC CALCULATION —

NAME AND ADDRESS OF CONTRACTOR ....
CONTRACT NO. .... CALCULATOR .... DATE ....
NAME OF OWNER AND OCCUPANT ....
ADDRESS ....
BUILDING OR PLANT UNIT NUMBER ....
DESCRIPTION OF HAZARD ....
AUTHORITY HAVING JURISDICTION ....

— SYSTEM REQUIREMENTS —

DESIGN PURPOSE: EXTINGUISHMENT ....
EXPOSURE PROTECTION ....
CONTROL .... FIRE PROTECTION ....
TYPE SYSTEM: AUTOMATIC .... MANUAL ....
DENSITY (G.P.M. PER SQ. FT.) ....
TOTAL NOZZLE FLOW REQUIRED .... G.P.M.
ALLOWANCE FOR INSIDE HOSE STATIONS .... G.P.M.
ALLOWANCE FOR OUTSIDE HYDRANTS .... G.P.M.
TOTAL WATER REQUIRED .... G.P.M. AT .... P.S.I.
REMARKS: ....

— WATER SUPPLY INFORMATION —

TYPE OF WATER SUPPLY: PUBLIC .... PRIVATE ....
STATIC PRESSURE IN P.S.I. ....
RESIDUAL PRESSURE:
G.P.M. FLOWING .... AT .... P.S.I.
ELEVATION .... LOCATION ....
ELEVATION .... LOCATION ....
PUMP DATA:
RATED CAPACITY .... G.P.M. AT .... P.S.I.
ELEVATION .... LOCATION ....
ELEVATION .... LOCATION ....
TANK DATA:
CAPACITY .... GALS.-ELEVATION ....
LOCATION ....
REMARKS: ....
....

Fig. A-7010.a. Sample Summary Sheet

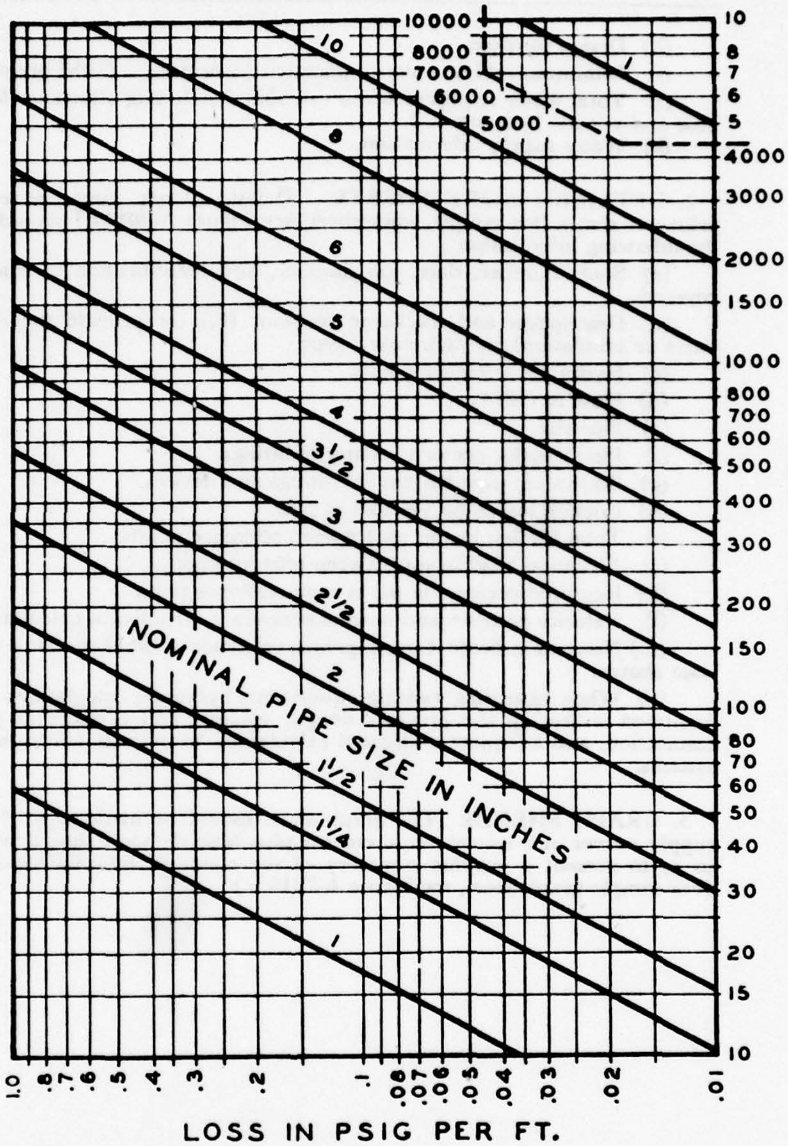

Fig. A-7010.b. Friction loss in schedule 40 steel pipe. Hazen & Williams C-120.

(h) Design purpose.

(i) Minimum rate of water application (density) . . . GPM per sq. ft.

(j) Total water requirements as calculated including allowance for inside hose and outside hydrants.

(k) Water supply information.

2. DETAILED WORK SHEETS. Detailed work sheets or computer print-out sheets (for sample work sheet, see Figure A-7010.f.) should contain the following information:

(a) Sheet number, date, job number, and identification of calculations covered.

(b) Description and discharge constant (K) (or provide the discharge curve or tabulation) for each nozzle type.

(c) Hydraulic reference points.

(d) Flow in GPM.

(e) Pipe size.

(f) Pipe lengths, center to center of fittings.

(g) Equivalent pipe lengths for fittings and devices.

(h) Friction loss in psi per foot of pipe.

(i) Total friction loss in psi between reference points.

(j) Elevation head in psi between reference points.

(k) Required pressure in psi at each reference point.

(l) Velocity pressure and normal pressure if included in calculations.

(m) Notes to indicate starting points, reference to other sheets or to clarify data shown.

(n) When extending existing equipment, hydraulic calculations are to be furnished indicating the previous design, volume, and pressure at points of connection, and adequate additional calculations to indicate effect on existing systems.

3. GRAPH SHEETS. The graph sheet should be made to $n^{1.85}$. Water supply curves and system requirements plus hose demand should be plotted so as to present a graphic summary of the complete hydraulic calculation. (For sample graph sheet, see Figure A-7010.h.)

4. ABBREVIATIONS & SYMBOLS.

The following standard abbreviations and symbols should be used.

Symbol or Abbreviation	Item
P	Pressure in psig.
gpm	Flow rate in U. S. Gallons per minute.
q	Flow increment in gpm to be added at a specific location.
Q	Summation of flow in gpm at a specific location.
P_t	Total pressure at a point in a pipe.
P_f	Pressure loss due to friction between points indicated in location column.
P_e	Pressure due to elevation difference between indicated points. This can be a plus value or a minus value. Where minus, the symbol (—) shall be used; where plus, no sign need be indicated.
P_v	Velocity pressure at a point in a pipe.
P_n	Normal pressure at a point in a pipe.
E	90° Elbow.
EE	45° Elbow.
Lt E	Long Turn Elbow.
Cr	Cross.
T	Tee, flow turned 90°.
GV	Gate Valve.
Del V	Deluge Valve.
DPV	Dry-Pipe Valve.
AL V	Alarm Valve.
CV	Swing Check Valve.
St	Strainer.
psig	Pounds per square inch gage.
v	Velocity of water in pipe in feet per second.
g	Acceleration due to gravity in feet per second per second (generally 32. or 32.16 is used).
K	A constant.
C	Hazen and Williams friction loss coefficient.
p	Frictional resistance per foot of pipe in psi per ft.
d	Actual internal diameter of pipe used, in inches.

5. FORMULAE.

a. Pipe friction losses should be determined on the basis of Hazen and Williams formula. (See Fig. A-7010.b.)

$$P = \frac{4.52\,Q^{1.85}}{C^{1.85}\,d^{4.87}}$$

b. The velocity pressure should be determined on the basis of

$$P_v = 0.433\,\frac{v^2}{2g}$$

Where v is the upstream velocity.

c. Normal pressure should be determined on the basis of

$$P_n = P_t - P_v$$

d. Hydraulic junction point calculations except for loops should be balanced to the higher pressure by the formula*

$$Q = K\sqrt{P} \text{ or } K = \frac{Q}{\sqrt{P}} \text{ or } \frac{Q^1}{Q^2} = \sqrt{\frac{P^1}{P^2}} \text{ (corrected for elevations)}$$

e. The discharge of a nozzle may be calculated by the formula*

$$Q = K\sqrt{P}$$

***NOTE: (1) P may be the total or normal pressure according to whether or not the velocity pressure is being included.**

(2) Piping may be looped to divide the total water flowing to the design area.

6. VELOCITY PRESSURE.

(a) The velocity pressure P_v may or may not be included in the calculations at the discretion of the designer.

NOTE: The omission of the velocity pressure from the calculations introduces an error that is generally on the safe side. However, under some conditions with high velocity, the velocity pressures should be considered.

(b) The velocity pressure P_v is a measure of the energy required to keep the water in a pipe in motion. At the end of the nozzle or end section of system (when considering junction of sections of systems) the total pressure available in the pipe at that point should be considered as causing flow. However, at other nozzles or junction points the pressure causing flow will be the normal pressure which is the total pressure minus the velocity pressure. Figure A-7010.c. may be used for determining velocity pressures, or velocity pressure may be determined by dividing the flow in gpm squared by the proper constant from Table A-7010.c.

(c) The following assumptions are to be used in applying velocity pressure to the calculations.

1. At any nozzle along a pipe, except the end nozzle, only the normal pressure can act on the nozzle. At the end nozzle, the total pressure can act.

2. At any nozzle along a pipe, except the end nozzle, the pressure acting to cause flow from the nozzle is equal to the total pressure minus the velocity pressure on the upstream side.

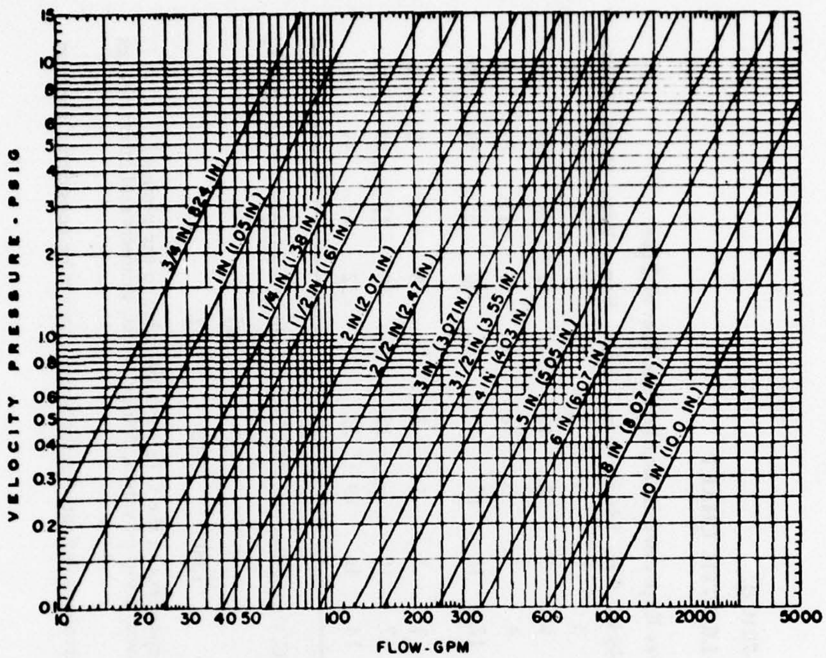

Fig. A-7010.c. Graph for the determination of velocity pressure.

TABLE A-7010.c.

Pipe Schedule	Pipe Size	Constant Based on Actual I. D.
40	1	1,080
40	1¼	3,230
40	1½	5,980
40	2	16,200
40	2½	33,100
40	3	78,800
40	3½	141,000
40	4	234,000
40	5	577,000
40	6	1,204,000
30	8	3,780,000
40	8	3,620,000

TABLE A-7010.d.

EQUIVALENT PIPE LENGTH CHART

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet of Pipe.													
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
45° Elbow	1	1	1	2	2	3	3	3	4	5	7	9	11	13
90° Standard Elbow	2	2	3	4	5	6	7	8	10	12	14	18	22	27
90° Long Turn Elbow	1	2	2	2	3	4	5	5	6	8	9	13	16	18
Tee or Cross (Flow Turned 90°)	4	5	6	8	10	12	15	17	20	25	30	35	50	60
Gate Valve	–	–	–	–	1	1	1	1	2	2	3	4	5	6
Butterfly Valve	–	–	–	–	6	7	10	–	12	9	10	12	19	21
Swing Check*	4	5	7	9	11	14	16	19	22	27	32	45	55	65

Use with Hazen and Williams C = 120 only. For other values of C, the figures in Table 7080 should be multiplied by the factors indicated below:

Value of C	100	120	130	140
Multiplying factor	0.713	1.00	1.16	1.32

(This is based upon the friction loss through the fitting being independent of the C factor applicable to the piping.) Specific friction loss values or equivalent pipe lengths for alarm valves, dry-pipe valves, deluge valves, strainers and other devices shall be made available to the authority having jurisdiction.

*Due to the variations in design of swing check valves, the pipe equivalents indicated in the above chart to be considered average.

3. To find the normal pressure at any nozzle except the end nozzle, assume a flow from the nozzle in question, and determine the velocity pressure for the total flow on the upstream side. Because normal pressure = total pressure − velocity pressure, the value of the normal pressure so found should result in a nozzle flow approximately equal to the assumed flow. If not, a new value should be assumed and the calculation repeated.

7. EQUIVALENT PIPE LENGTHS OF VALVES & FITTINGS.

(a) Table A-7010.d. should be used to determine equivalent lengths of pipe for fittings.

(b) Specific friction loss values or equivalent pipe lengths for deluge valves, strainers, and other devices shall be made available.

8. CALCULATING PROCEDURE.

In order to maintain consistency in hydraulic calculations, whether done by hand or by computer, the following rules should be followed. Experience has shown that good results are obtained if the calculations are made in accordance with these rules. It is recognized that satisfactory results may be obtained by using other methods. However, in order to simplify the checking of calculations and to obtain more consistent correlation between calculated system characteristics and actual system characteristics it is desirable to use a standard method.

(a) The first work sheet should start at a remote nozzle and proceed directly to a point of known or proposed water supply. Branch calculations should be made on subsequent sheets.

(b) Include the friction loss on all pipe and devices such as valves, meters, and strainers.

(c) Include all fittings where a change in direction of the flow occurs, as follows:

1. Calculate the loss for a tee or a cross where flow direction change occurs, based on the equivalent pipe length for the smaller size of the tee or cross in the path of the turn. Do not include any loss for that portion of the flow which passes straight through the run of a tee or a cross.

2. Calculate the loss of reducing elbows based on the equivalent feet value of the smallest outlet. Use the equivalent feet value for the "standard elbow" on any abrupt ninety degree turn, such as the screw type pattern. Use the equivalent feet value for the "long turn elbow" on any sweeping ninety degree turn, such as a flanged, welded, or mechanical joint type elbow.

3. Friction loss should be excluded for tapered reducers and for the fitting directly supplying the spray nozzle.

(d) Include all elevation changes affecting the discharge and/or the total required pressure where it occurs.

(e) Piping may be looped to divide the total water flowing to the design area.

(f) The water allowance for outside hydrants when served from the same underground mains may be added to the system requirement at the system connection to the underground main. The total water requirement should then be calculated through the underground main to the point of supply.

(g) Orifice plates should not be used for balancing the system.

(h) Calculate pipe friction loss in accordance with the Hazen and Williams formula using "C" value of 120 for black or galvanized steel pipe, C-140 for cement lined cast iron pipe or copper tubing, and C-100 for unlined cast iron pipe. These coefficients contemplate the use of the actual pipe internal diameter in the formula.

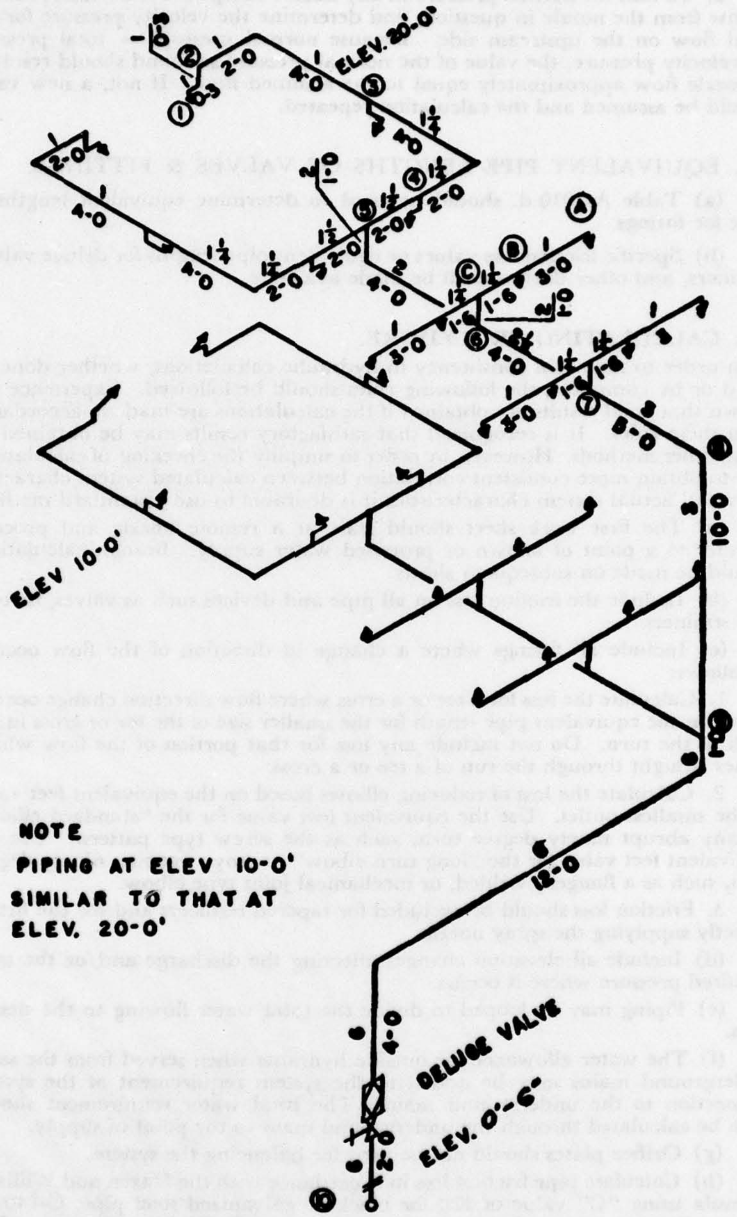

Fig. A-7010.e. Drawing of Water Spray System Used for Sample Calculation shown in Figs. A-7010.f. and A-7010.g.

9. SAMPLE CALCULATIONS.

Figure A-7010.e. shows a hypothetical water spray system layout. Figure A-7010.f. shows a sample calculation for this system using pipe sizing and nozzles with constants such that the velocity pressures generally exceed 5 percent of the total pressures, and the designer elected to include velocity pressures. Figure A-7010.g. shows a sample calculation for this system, using pipe sizing and nozzles with constants such that velocity pressures are *less* than 5 percent of the total pressures, and the velocity pressures were *not* included in the calculation.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig. A-7010.e — SHEET NO. 1 OF 2
All Nozzles Type N90 — BY J.E.C
(Nozzle Discharge Constant 9.0) — DATE 12-3-68
JOB NO. 1571

Nozzle Ident. & Location	Flow in G.P.M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss p.s.i./foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N90 ①	q 40.2 Q 40.2	1	E=2.0	LGTH. 0.5 FTG. 2.0 TOT. 2.5	.47	Pt 20.0 Pe — Pf 1.2	Pt Pv Pn	21.0'	$q_1 = 9.0\sqrt{20}$ 40.2
 ②	q — Q 40.2	1	2E=4.0	LGTH. 6.0 FTG. 4.0 TOT. 10.0	.47	Pt 21.2 Pe — Pf 4.7	Pt Pv Pn		
1-N90 ③	q 40.6 Q 80.8	1¼	E=3.0	LGTH. 6.0 FTG. 3.0 TOT. 9.0	.46	Pt 25.9 Pe — Pf 4.1	Pt 25.9 Pv 2.0 Pn 23.9		$q_3 = 8.3\sqrt{23.9} = 40.6$ For K_3 Calcs, See ①
1-N90 ④	q 43.5 Q 124.3	1½	T=8.0	LGTH. 2.0 FTG. 8.0 TOT. 10.0	.48	Pt 30.0 Pe — Pf 4.8	Pt 30.0 Pv 2.6 Pn 27.4		$q_4 = 8.3\sqrt{27.4} =$ 43.5
3-N90 ⑤	q 124.3 Q 248.6	2	E=5.0	LGTH. 5.0 FTG. 5.0 TOT. 10.0	.50	Pt 34.8 Pe 0.4 Pf 5.0	Pt Pv Pn		
4-N90 ⑥	q 180.0 Q 428.6	2½		LGTH. 4.0 FTG. — TOT. 4.0	.58	Pt 40.2 Pe — Pf 2.3	Pt 40.2 Pv 5.5 Pn 34.7	20.0'	$q_6 = 30.6\sqrt{34.7} = 180$ For K_6 Calcs, See ②
4-N90 ⑦	q 188.0 Q 616.6	3	E=7.0	LGTH. 5.0 FTG. 7.0 TOT. 12.0	.40	Pt 42.5 Pe — Pf 4.8	Pt 42.5 Pv 4.8 Pn 37.7		$q_7 = 30.6\sqrt{37.7} =$ 188
 ⑧	q — Q 616.6	3		LGTH. 10.0 FTG. — TOT. 10.0	.40	Pt 47.3 Pe 4.3 Pf 4.0	Pt Pv Pn		
14-N90 ⑨	q 640.0 Q 1256.6	6	2E=28.0 Dry V=10.0 G.V.=3.0	LGTH. 19.0 FTG. 41.0 TOT. 60.0	.054	Pt 55.6 Pe 4.1 Pf 3.2	Pt 55.6 Pv 1.3 Pn 54.3	10.0'	$q_9 = 86.8\sqrt{54.3} = 640.$ For K_9 Calcs, See ③
 ⑩	q — Q 1256.6 ✓			LGTH. FTG. TOT.		Pt 62.9 ✓ Pe Pf	Pt Pv Pn	0.5'	
	q Q			LGTH. FTG. TOT.		Pt Pe Pf	Pt Pv Pn		Note: Flow Test at Yard Hydrants Static Pressure 89 p.s.i.
	q Q			LGTH. FTG. TOT.		Pt Pe Pf	Pt Pv Pn		Residual Pressure: 80 p.s.i. Flow: 1300 g.p.m. ~2300 g.p.m. available at 62.9 p.s.i.

Fig. A-7010.f. Calculation of System shown in Fig. A-7010.e. with Velocity Pressure Included.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig. A-7010-e
All Nozzles Type N90
(Nozzle Discharge Constant 9.0)

SHEET NO. 2 OF 2
BY J. E. C.
DATE 12-3-68
JOB NO. 1571

Nozzle Ident. & Location	Flow in G. P. M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss p.s.i./foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N90 ①	q 40.2 Q 40.2	1	E=2.0 T=5.0	LGTH. 0.5 FIG. 7.0 TOT. 7.5	.47	Pt 20.0 Pe — Pf 3.5	Pt Pv Pn		$K_B = \frac{40.2}{\sqrt{23.5}} = 8.3$
	q Q			LGTH. FIG. TOT.		Pt 23.5 Pe Pf	Pt Pv Pn		
②	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
1-N90 Ⓐ	q 40.2 Q 40.2	1		LGTH. 3.0 FIG. — TOT. 3.0	.47	Pt 20.0 Pe — Pf 1.4	Pt Pv Pn	21.0'	
1-N90 Ⓑ	q 39.6 Q 79.8	1¼	T=6.0	LGTH. 1.5 FIG. 6.0 TOT. 7.5	.44	Pt 21.4 Pe — Pf 3.3	Pt 21.4 Pv 2.0 Pn 19.4		
2-N90 Ⓒ	q 79.8 Q 159.6	2	T=10.0	LGTH. 1.0 FIG. 10.0 TOT. 11.0	.23	Pt 24.7 Pe 0.4 Pf 2.5	Pt Pv Pn		$K_C = \frac{159.6}{\sqrt{27.6}} = 30.6$
	q Q			LGTH. FIG. TOT.		Pt 27.6 Pe Pf	Pt Pv Pn	20.0'	
Lower Pipe Level ③	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
14-N90 Ⓓ	q Q 616.6	3	T=15.0	LGTH. 5 FIG. 15 TOT. 20	.40	Pt 42.5 Pe 8.0 Pf 50.5	Pt Pv Pn		$K_D = \frac{616.6}{\sqrt{50.5}} = 86.8$
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		
	q Q			LGTH. FIG. TOT.		Pt Pe Pf	Pt Pv Pn		

Fig. A-7010.f. Continued.

Notes for Figure A-7010.f.

The velocity pressure Pv is determined by trial. It is necessary to estimate the flow Q in the pipe on the upstream side of the nozzle to determine a trial Pv which is used to determine a trial Pn, a trial q, and a trial Q. After determining the trial Q use this value to determine a new Pv. If the new Pv is approximately equal to the trial Pv consider the trial Q to be the actual Q and proceed with the calculations. If the Pv does not check with the trial Pv estimate Q again and proceed with successive corrections until an actual Pv is obtained that checks with a trial Pv.

The flow from nozzles may be obtained from discharge curves rather than individual calculations at the preference of the calculator. Similarly, flow characteristics of lines or sections of systems may be obtained by plotting results on charts made up to $n^{1.85}$ or n^2 rather than by calculating constants (K — values).

Figure No. A-7010.g. shows a sample calculation for the system shown in Figure No. A-7010.e. using pipe sizing and nozzles with constants such that velocity pressures are less than 5 percent of the total pressures, and the velocity pressures were not included in the calculation.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig A-7010-e
All Nozzles Type N-30
(Nozzle Discharge Constant 30)

SHEET NO. 1 OF 2
BY J. E. C.
DATE 12-3-68
JOB NO. 1572

Nozzle Ident & Location	Flow in G.P.M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss p.s.i./foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N30 ①	q 13.4 Q 13.4	1	1E = 2.0	LGTH .5 FTG 2.0 TOT 2.5	.06	PT 20.1 PE — PF 0.2	PT PV PN	21.0'	$q_1 = 3.0\sqrt{20.1} =$ 13.4
 ②	q — Q 13.4	1	2E = 4.0	LGTH 6.0 FTG 4.0 TOT 10.0	.06	PT 20.3 PE — PF 0.6	PT PV PN		
1-N30 ③	q 13.5 Q 26.9	1¼	1E = 3.0	LGTH 6.0 FTG 3.0 TOT 9.0	.06	PT 20.9 PE — PF 0.5	PT PV PN		$q_3 = 2.95\sqrt{20.9} = 13.5$ See ◇1 for K_3 Calcs.
1-N30 ④	q 13.6 Q 40.5	1½	1T = 8.0	LGTH 2.0 FTG 8.0 TOT 10.0	.06	PT 21.4 PE — PF 0.6	PT PV PN		$q_4 = 2.95\sqrt{21.4} = 13.6$
3-N30 ⑤	q 40.5 Q 81.0	2	1E = 5.0	LGTH 5.0 FTG 5.0 TOT 10.0	.06	PT 22.0 PE 0.4 PF 0.6	PT PV PN		
4-N30 ⑥	q 56.1 Q 137.1	2½		LGTH 4.0 FTG — TOT 4.0	.07	PT 23.0 PE — PF 0.3	PT PV PN	20.0'	$q_6 = 11.7\sqrt{23.0} = 56.1$ See ◇2 for K_6 Calcs.
4-N30 ⑦	q 56.5 Q 193.6	3	1E = 7.0	LGTH 5.0 FTG 7.0 TOT 12.0	.05	PT 23.3 PE — PF 0.6	PT PV PN		$q_7 = 11.7\sqrt{23.3} = 56.5$
 ⑧	q — Q 193.6	3		LGTH 10.0 FTG — TOT 10.0	.05	PT 23.9 PE 4.3 PF 0.5	PT PV PN		
14-N30 ⑨	q 211.0 Q 404.6	6	2E = 20.0 Dry V = 10.0 GV = 3.0	LGTH 19.0 FTG 41.0 TOT 60.0	.007	PT 28.7 PE 4.1 PF 0.4	PT PV PN	10.0'	$q_9 = 39.3\sqrt{28.7} = 211$ See ◇9 for K_9 Calcs
 ⑩	q — Q 404.6 ✓			LGTH FTG TOT		PT 33.2 PE PF	PT PV PN	0.5'	
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		Note: See Fig. A-7090-d for Water Supply Information.
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG TOT		PT PE PF	PT PV PN		

Fig. A-7010.g. Calculation of System shown in Fig. A-7010.e. with Velocity Pressure not Included.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig. A-7010-e — SHEET NO. 2 OF 2
All Nozzles Type N-30 — BY J. E. C.
(Nozzle Discharge Constant 3.0) — DATE 12-3-68
JOB NO. 1572

Nozzle Ident. & Location	Flow in G.P.M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss p.s.i./foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N30 1	q 13.4 Q 13.4	1	1E: 2.0 1T: 5.0	LGTH 0.5 FTG 7.0 TOT. 7.5	.06	PT 20.1 PE — PF 0.5	PT PV PN		$K_3 = \frac{13.4}{\sqrt{20.6}} = 2.95$
	q Q			LGTH. FTG. TOT.		PT 20.6 PE PF	PT PV PN		
2	q Q			LGTH. FTG. TOT		PT PE PF	PT PV PN		
1-N30 A	q 13.4 Q 13.4	1		LGTH 3.0 FTG. — TOT 3.0	.06	PT 20.1 PE — PF 0.2	PT PV PN		
1-N30 B	q 13.5 Q 26.9	1¼	1T = 6.0	LGTH. 1.5 FTG 6.0 TOT 7.5	.06	PT 20.3 PE — PF 0.5	PT PV PN		
2-N30 C	q 26.9 Q 53.8	2	1T = 10.0	LGTH. 1.0 FTG 10.0 TOT 11.0	.03	PT 20.8 PE 0.4 PF 0.3	PT PV PN		$K_C = \frac{53.8}{\sqrt{21.5}} = 11.7$
	q Q			LGTH. FTG. TOT.		PT 21.5 PE PF	PT PV PN		
LOWER PIPE 3	LEVEL q Q			LGTH. FTG. TOT.		PT PE PF	PT PV PN		
14-N30	q Q 193.6	3	1T = 15.0	LGTH. 5.0 FTG 15.0 TOT 20.0	.05	PT 23.3 PE — PF 1.0	PT PV PN		$K_9 = \frac{193.6}{\sqrt{24.3}} = 39.3$
	q Q			LGTH FTG TOT		PT 24.3 PE PF	PT PV PN		
	q Q			LGTH. FTG. TOT		PT PE PF	PT PV PN		
	q Q			LGTH. FTG. TOT.		PT PE PF	PT PV PN		
	q Q			LGTH. FTG TOT		PT PE PF	PT PV PN		
	q Q			LGTH. FTG. TOT.		PT PE PF	PT PV PN		
	q Q			LGTH. FTG. TOT		PT PE PF	PT PV PN		
	q Q			LGTH FTG. TOT.		PT PE PF	PT PV PN		
	q Q			LGTH. FTG. TOT		PT PE PF	PT PV PN		

Fig. A-7010.g. Continued

Note for Figure A-7010.g.

The flow from nozzles may be obtained from discharge curves rather than individual calculations at the preference of the calculator. Similarly, flow characteristics of lines or sections of systems may be obtained by plotting results on charts made up to $n^{1.85}$ or n^2 rather than by calculating constants (K — values).

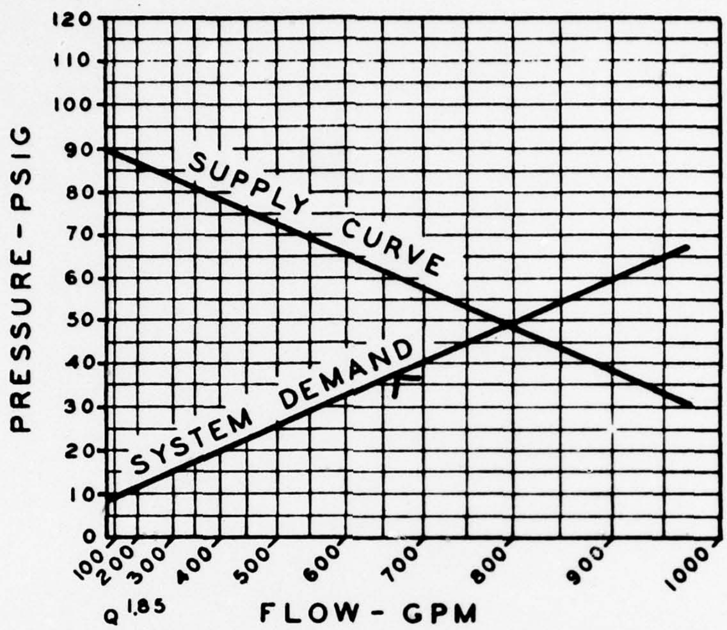

Fig. A-7010.h. Sample Graph Sheet

Graphic summary of hydraulic calculations shown in Figure A-7010.h., and assuming 250 gpm outside hydrant flow requirements and 4.0 psi underground friction loss.

System requirements = 404.6 gpm at 33.21 psi

Hose Stream requirements = 250 gpm; additional 4.0 psi required

TOTAL WATER REQUIREMENTS = 654.6 gpm at 37.21 psi
Pe = 8.8 psi

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